BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B71 03005

SUBJECT: Skylab Leakage Propulsion Models
Case 620

DATE: March 2, 1971

FROM: P. G. Smith

ABSTRACT

Three methods of calculating torque due to cabin atmosphere leakage are presented. One yields a worst-case value of 0.26 ft-lb, and the other two, which are based on different assumptions, yield estimated values of 0.13 and 0.08 ft-lb. Only with a more detailed leakage specification can more refined estimates of leakage torques be made.

(NASA-CR-117341) SKYLAB LEAKAGE PROPULSION MODELS (Bellcomm, Inc.) 8 p

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MEMORANDUM FOR FILE

Introduction

Cabin atmosphere will leak from the pressurized Skylab modules, and in so doing, it will create a torque on the vehicle that must be reckoned with in assessing attitude control system performance. Analytical estimation of the torque is subject to large errors inasmuch as magnitudes, locations, and directions of the leaks are poorly known, even in a probabilistic sense. In view of the circumstances, three different means of computing leakage torque are presented here; in each case the rationale is described and numerical values are given.

Elements in Common

All three models share the following properties.

Single leak in each module (and interface). This is a worst-case condition because maximum leakage is specified on a per module basis [1].

Leakage at maximum allowable rate. Unless stated otherwise, this is the rate given in the Specification [1], and it is clear that this too is a worst-case condition.

Direction normal to Workshop longitudinal axis. This tends to maximize the lever arm associated with a given leak, so it is also conservative.

Thrust vectors all pass through Workshop centerline. This is an assumption, which together with the approximation that the vehicle mass center also lies on the centerline, simplifies the problem. Note that this condition is not conservative since it eliminates leakage torques about the longitudinal axis, but one may argue that the lever arms associated with such torques should be small anyway.

Specific impulse of 54 sec. This value, calculated in accordance with Reference 2, is considered realistic.

Maximum Torque Model

This model gives an upper bound on leakage troque. Flow rates from Reference 1 are used with two exceptions:

OWS leakage is reduced from 5 to 3 lb/day to allow for the amount that is expected to pass through the waste tank "nonpropulsive" vents [3]; and

CM leakage is raised from 2.4 to 4.8 lb/day, which the writer understands to be the contractual maximum allowable value [4].

Two pieces of information are needed to complete the model, namely, the longitudinal locations of the leaks and their directions, which are already constrained to be normal to the longitudinal axis. Consistent with this worst-case approach, the locations used are those on each module farthest from the vehicle mass center, and the directions are such that all leaks on one side of the mass center are aligned and all leaks on the other side are aligned but in the opposite direction so as to produce the largest possible torque. The actual direction of the resultant torque is left open so that leakage torque may be added to known torques, such as those due to gravity and venting, in the most detrimental way.

It is clear that this model involves a possible but highly improbable combination of worst cases.

Half Maximum Torque Model

In view of the fact that the maximum torque is quite unlikely to occur, one can work with some fraction of the maximum value, the fraction being chosen more or less arbitrarily. One half has been used [5], and one can justify this fraction on the grounds of Apollo leak test results [6], which show that with a sole exception, all Command Modules leaked at less than half the allowable rate. This justification is subject to question, however, on grounds of the differences between the CM and the other Skylab modules.

RSS Model [7]

In this model, proposed by and used by MSFC, three of the assumptions made in the maximum torque model are softened. Specifically,

leaks are taken to be located at the module's mass centers rather than at their extremities,

the leakage directions are not all assumed to be aligned as before, and

the 2.4 lb/day CM leakage rate given in Reference 1 is used in place of the 4.8 lb/day value.

Nonalignment is handled by root sum squaring the individual leakage torques so as to arrive at a composite torque (when the leaks are aligned the composite torque is obtained by adding magnitudes).

This torque is divided by $\sqrt{2}$, and then added to both the y and z axis venting torques in such a way that the resultant torque is as large as possible.

The model is named after the root sum square process involved, but the process itself seems to have no justification in this application; it is merely a way of combining values.

Numerical Values

The table gives numerical data for the maximum torque and rss models, based on a mass center located at stn. 647 (Orbital Assembly coordinates). The respective angular impulses are 1450 and 431 ft-lb-sec/orbit (5600 sec orbit), and thus the value for the half maximum torque model is 725 ft-lb-sec/orbit.

Discussion

The assumptions upon which the half maximum torque and rss models rest are questionable. The writer and others have proposed other leakage models as well, but all are based on questionable assumptions regarding the nature of the leakage. Only the maximum torque model stands on firm ground, but its conservatism impairs its usefulness.

What would help the situation is not more sophisticated models or sets of assumptions but rather a more detailed leakage specification and test procedures to back it up. The specification and the tests should ensure that leakage will be well distributed so that self-cancellation effects are certain.

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Attachment
Table
References

Numerical Values for Two Models

Module or Interface	Maximum Torque Model			RSS Model		
	flow rate lb/day	lever arm ft	torque ft-lb	flow rate lb/day	lever arm ft	torque ft-lb
CM	4.8	33.6	.101	2.4	31.1	.047
CM/MDA	1.2	28.0	.021	1.2	28.0	.021
MDA	1.8	28.0	.032	1.8	18.6	.021
MDA Port 3	0.2	19.4	.002	0.2	19.4	.002
MDA/AM	0.6	10.8	.004	0.6	10.8	.004
AM	2.5	10.8	.017	2.5	2.4	.004
AM/OWS	0.3	- 6.3	-.001	0.3	- 6.3	-.001
OWS	3.0	-42.9	-.080	3.0	-28.4	-.053

Maximum magnitude = .259

Root sum square = .077

References

1. AAP Cluster Requirements Specification, MSFC, August 8, 1969, p. A-5.

2. Smith, P. G., "The Effect of Venting and Leakage on AAP Cluster Attitude Control Propellant Requirements," Bellcomm Memorandum for File, October 17, 1967; see equation (12) of Appendix.

3. Personal communication, Robert Gershman, McDonnell Douglas-West, August 27, 1970.

4. Personal communication, James Ross and Elza Confer, North American Rockwell, August 28, 1970.

5. Levidow, W., "Effect of Venting and Leakage Torque on Attitude Control of Skylab Orbital Assembly by CMGs," Bellcomm Technical Memorandum TM-71-1022-1, March 2, 1971.

6. CSM Technical Status Review handout, Downey, California, May 20, 1970, pp. 25-40.

7. Personal communication, Harry Buchanan, MSFC, November 30, 1970.

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